SHANGHAI’S NATURAL GAS MARKET AND THE ROLE OF LNG: STATUS AND PROSPECTS

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Abstract
Since the introduction of LNG into Shanghai’s energy mix in 2009, LNG imports started to make an important contribution to the volume and diversity of city’s gas supplies. Its market share reached 50% of the total consumption in 2013. LNG is thus considered as an increasingly important part of the city’s supply and deliverability network.

However, Shanghai’s gas market underwent significant structural changes in recent years. Industrial gas consumption has stagnated, while gas use in residential and commercial and power generation has started to take larger shares in the consumption mix. These trends have significant implications for LNG as it can bring better flexibility into the system. As a result, LNG has been increasingly used for peak shaving.

After reviewing the factors affecting gas demand in Shanghai and supply options, this paper suggests that the potential for gas demand growth will be in the residential and commercial and power sectors. Therefore, the future role for LNG is to continue to constitute an important contribution to gas supply and remain necessary to provide much needed flexibility to meet peak demand.
Shanghai's Natural Gas Market and the Role of LNG: Status and Prospects

1. Introduction

Since the introduction of LNG into Shanghai’s energy mix in 2009, LNG imports started to make an important contribution to the volume and diversity of city's gas supplies. Its market share reached 50% of the total gas consumption in 2013. LNG is thus considered as an increasingly important part of the city’s supply and deliverability network. However, Shanghai’s gas market underwent significant changes in recent years. Total gas consumption has slowed down with annual growth rate dropping from 16.8% in 2012 to 9.9% in 2013 and even lower rates since then. This is in contrast to the decade long double-digit growth achieved before 2013.

At the sectoral level, gas consumption in industry peaked in 2013 and has since declined. Gas consumption in the residential and commercial sector reversed its declining trend and started to account for nearly half of the total consumption. In addition, gas used for power generation started to outpace its use in industry. Several factors such as economic restructuring, energy savings, and demand management contributed to the decline in the annual growth rate and gas consumption structural changes. These trends have significant implications for the use of LNG. The characteristics of LNG as a reliable and flexible source of supply have led to its increasing use for peak shaving in Shanghai.

The main question of this article is, what is the role of LNG in the future Shanghai gas market? The research starts with the review of the historic consumption patterns of gas in Shanghai to provide a better understanding of the market dynamics. Future demand drivers and constraints are also examined to indicate the possible trend of gas demand and the role LNG will play in the gas market.

The structure of this paper is organized as follows. After this section that serves as introduction, the second section sets the scene by providing an overview of energy and natural gas consumption in Shanghai. The third section focuses on the drivers and constraints of gas demand. It also explores the potential for additional gas consumption and highlights the main factors that are likely to influence the trends of gas demand. Then in section four, the supply sources are reviewed in order to meet the growing demand for gas, with a special focus on the role of LNG in the mix. Finally, section five draws together some conclusions.

2. The role of natural gas in energy market

2.1 Overview of energy market

Two distinct patterns can be discerned from the development of energy consumption in Shanghai between 2000 and 2016 (Figure 1). Broadly in line with sustained economic growth, Shanghai’s energy consumption increased rapidly during the period of 2000-2010, with annual growth rate reaching about 7%. As the economy entered an age generally known as the ‘new normal’ - slower and qualitatively different growth, energy consumption also slowed down accordingly. In fact, an average annual growth rate of 1.3% was recorded in the period 2011-2015.
The significant decline can be attributed to several factors such as economic restructuring, energy savings, and demand management.¹

Figure 1: Evolution of the total energy consumption, 2000-2016

![Graph showing the evolution of total energy consumption and growth rate from 2000 to 2016.](image)


Improving energy consumption structure through the use of clean energy such as natural gas has been a long-term strategy in the municipal government’s energy development five-year plans (FYPs). In the 10th, 11th and 12th FYPs, a recurring theme is to reduce the share of coal consumption in primary energy mix. Indeed, the targets have been met at the end of each FYP period. For example, the period of 2000-2015 witnessed a sharp decline of the share of coal consumption in the primary energy mix from 66% in 2000 to 36% in 2015 (Figure 2). In the same period, the share of gas in the primary mix increased from merely 1% to 10%. Thus, cleaner energy alternatives such as gas and imported electricity² gained market share at the expense of coal, which resulted in significant improvements in Shanghai’s energy structure.

¹ Shanghai Development and Reform Commission (2016).
² Shanghai imports electricity from other regions, mainly in the form of hydro-based electricity.
Shanghai is still in the process of promoting economic transformation and upgrading. The municipal government expects overall energy demand to grow slowly. According to the 13th FYP (2016-2020), the target is to limit the total primary energy consumption to 125 million tons of coal equivalent (Mtce) in 2020, with an annual growth rate of 1.9%. In addition, improving energy mix continues to be one of the main policy requirements, aiming to lower the share of coal in energy mix to 33% and increase that of gas to 12% or higher. The municipal government predicts gas consumption to reach 10 billion cubic meters (Bcm) in 2020.

2.2 Trends in natural gas consumption

Natural gas consumption grew rapidly in the period 2001-17, at an average 25% per year (Figure 3). In absolute terms, total gas consumption increased from 330 million cubic meters (Mcm) in 2001 to 8.3 Bcm in 2017. Two significant developments can be observed in the year 2004 and 2009, which corresponds to the introduction of the West-East pipeline gas and imported LNG respectively, indicating significant demand potential for natural gas.

However, gas demand growth has been modest in recent years, with single-digit rates recorded since 2013. A number of factors explain the slowdown in gas consumption growth. First, many energy intensive industries are relocated out of the city as a result of the changing industrial structure of the economy, which in turn means less energy consumption. Moreover, the falling oil prices in recent years eroded the competitiveness of gas against fuel oil, which in turn led to less demand for gas.\(^3\) In addition, after years of intensive coal reduction campaign, dispersed use of coal has been nearly eliminated or replaced with gas. As a result, the potential for further substitution of coal with gas is limited.\(^4\) In fact, gas consumption reached 7.7 Bcm in 2015, much less than the target of 10 Bcm set in the energy development 12th FYP.

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\(^3\) Li (2015).

\(^4\) Tang and Huang (2015).
2.3 Natural gas consumption at sectoral level

In Shanghai, natural gas is mainly used in three sectors: (1) residential and commercial, (2) industry and (3) power generation. The residential and commercial sector has traditionally been the largest consumer. Industry and power generation come in the second and third with similar shares (Figure 5).

Figure 3: Natural gas consumption, 2000-2017 (Bcm)

Source: Shanghai Statistical Yearbook, various years.

Between 2008 and 2013, three sectors were all on the rise, although the share of each sector in total gas consumption varies. For example, the share of the residential and commercial sector shows a declining trend from
about 60% in 2008 to 48% in 2013 (Figure 5). This is accompanied by the increase in the share of gas use in industry (nearly 30%) and in power generation (25%).

The year 2013 marks a watershed year for gas consumption. Gas use in industry started to stagnate in both absolute terms and the share in consumption mix (Figures 4 and 5). Apart from the fact that total energy consumption slowed down as a result of economy restructuring, the relative price of gas against alternative energy sources appears to play an important role in the decline of gas consumption in this sector. In industry, gas competes directly with alternative fuels such as fuel oil and coal. The plunge of international oil prices and subsequently the lower fuel oil prices resulted in less competitiveness of gas against fuel oil. As the demand for oil and coal picked up, the displacement of coal with gas slowed down.

However, residential and commercial gas consumption reversed its declining trend and started to account for more share of total consumption. One of the contributing factors is the growing number of households converted from coal to gas for heating. Over the past ten years, proportion of population with access to gas rose almost threefold. As for gas use in the power sector, the share stayed on the same level. In 2017, the residential and commercial sector still represents the largest consumer (51%), followed by the power sector (26%), and industry (23%).

Figure 5: Share of natural gas consumption at sectoral level, 2008-2017

Source: Data from SNGC, various years.

3 Factors affecting natural gas demand

This section analyses the drivers and constraints as well as fluctuations in demand for gas rather than provides a quantitative demand forecasting. The objective is to present a general outlook of the demand for gas in the coming years, which could shed light on the role of LNG in the future gas market.

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5 Li (2015).
3.1 Drivers and constraints

Gas prices

Analysis of the demand for gas in Shanghai by prices alone presents considerable problems, partly because end-user prices have been strictly regulated by the government. Figure 6 depicts the monthly industrial gas demand against industrial gas prices over the period 2013 to 2017. The increase in industrial gas prices in late 2014 appeared to slow the demand in 2015. However, when the prices were revised downward in late 2015, the demand went down further in the first half of 2016. Empirical evidences suggest that limited pricing impact on the demand.

Figure 6: Sensitivity of industrial gas demand to price, 2013-2017

Source: Shanghai Development and Reform Commission natural gas price notices, various years, monthly consumption from Shanghai Natural Gas Grid Company (SNGC) data.

Similar observations can be made in the residential gas prices. Largely for social stability, the residential prices have remained at low levels and stable over a long period. In addition, residential prices have been kept lower than industrial prices, implying that profits from industrial users are used to subsidize prices to residential users. Deregulation started in 2014, when residential prices were hiked by 20% with the introduction of tiered pricing. Nevertheless, taking households disposable income in 2016 for example, gas costs only account for about 3% of housed expenditures, suggesting much greater affordability for gas. The continuing rise of gas consumption in the residential sector since 2008 (Figure 4) implies that other non-price factors are playing a part in driving gas demand.

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7 Bai et al. (2016).
8 Shanghai Development and Reform Commission (2014).
Residential and commercial gas demand

Natural gas, essentially used for heating purposes in the residential and commercial sector, requires stable and continuous supply. The demand for gas is driven by factors such as economic development, proportion of population with access to gas, per capita gas consumption, and weather temperature. After years of infrastructure expansion, all the districts and counties in Shanghai are now covered by natural gas trunk pipelines. With the growing trend of urbanization, the local distribution company in Shanghai aims to extend gas pipelines to all suburbs, which currently have no gas access, by the end of 2020.\(^9\)

Looking to the near future, given that residential gas consumption is prioritized in the government policy (e.g., the 13\(^{th}\) FYP), it is likely that residential gas price will be kept at relatively lower levels for some considerable time. This adds additional incentives to use the fuel. With the economy continuing to grow and the expansion of distribution network, growing demand for gas in residential is expected in Shanghai. Also, as the economy continues to transform from an industry-based to a service-based economy, commercial demand for gas is expected to rise. Nevertheless, it should be noted that a larger share of residential and commercial gas demand could put an increasing strain on existing gas infrastructure, especially during winter peaking period.\(^{10}\) This in turn calls for a more flexible supply of gas.

Gas for power generation

In order to diversify away from coal-dominated power generation capacity, gas-fired power generation has long been promoted in the municipal government’s energy FYPs. As seen in Figure 7, the installed capacity of gas-fired power generation units gradually increases its share in the total generation capacity mix at the expense of coal and oil. In 2015, coal generation capacity contributed the largest share of total generation capacity at about 62%, with gas plants 29% and renewables 9% filling the remainder.

\(^9\) Shenergy (Group) Company (2016).
\(^{10}\) Peng (2017).
Nevertheless, electricity generated by gas-fired power plants only accounts for about 7% of the total power generation in 2016. This suggests that gas-fired power generation units are having low load factors. Recent research indicated that the combine-cycle gas turbine (CCGT) units ran at 1500-1600 hours a year and single cycle gas turbine units were only used for 300 hours a year.\textsuperscript{11}

The main reason is that gas-fired power generation lacks of competitiveness relative to coal-fired power generation. This is due in part to the relatively small difference in capital costs between coal and gas power plants.\textsuperscript{12} More importantly, fuel cost accounts for the majority of power generation cost with the price of gas nearly double that of coal.\textsuperscript{13} As result, it is more expensive to operate a gas-fired power plant compared to a coal-fired power plant.

In order to improve the competitiveness of gas-fired power generation, a two-part tariff was introduced with a capacity component on top of the on-grid price for gas-fired generators.\textsuperscript{14} The capacity component in the form of subsidies essentially enables gas-fired generators to recover capital investment costs. Still, gas-fired plants are only cost-competitive in providing peaking services. In a sense, the existing plants could potentially generate more electricity if the economics of gas-fired generation can be further enhanced.

In the 13\textsuperscript{th} energy FYP, Shanghai plans to advance gas-fired generation but in an orderly manner, aiming to increase installed capacity from 5.9 GW to 8 GW by 2020. Peaking units are encouraged in anticipation of the widening gap between the peak and valley power demand. It is a strategic choice for Shanghai to build sufficient gas-fired peaking plants.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure7.png}
\caption{Evolution of generation capacity by fuels, 2005, 2010 and 2015 (\%)}
\end{figure}

Source: Shanghai Energy Development FYPs, various years.

\textsuperscript{11} Shanghai Municipal Gas Association (2017).
\textsuperscript{12} Kahrl et al. (2013).
\textsuperscript{13} Shanghai Economic and Information Commission (2017).
\textsuperscript{14} Shanghai Bureau of Pricing (2012).
In short, although the subsidization of gas-fired power generation is favorable to short-term gas demand, the sustainability of such policy-driven approach is questionable. As a result, uncertainties remain over the scale of its future development. Nevertheless, if gas-fired generators continue to be used mainly for peaking purpose, it will in turn call for flexible supply of gas such as LNG.

**Gas use in industry**

Gas is mainly used as a fuel in industrial applications. Major end-users include iron and steel, chemical, and large manufacturers. The demand for gas will depend upon industrial structural adjustments and environmental protection policy. According to the 13th FYP, Shanghai will accelerate the economic adjustment process to move away from heavy industry to an economy dominated by services. As a result, the potential for gas demand in large applications remains limited.

Environmental protection policy has been an important driver in the demand for gas in coal-to-gas conversion. In order to curb air pollution, Shanghai embarked on the replacement of dispersed use of coal in industrial boilers with clean energies as early as the year 2000 when gas was first introduced in the city. A series of policies and measures have been implemented and significant progress has been made. During the 12th FYP period (2011-2015), a total of 5153 small and inefficient coal boilers were either closed or converted to heavy fuel oil-fired or gas-fired ones. Accordingly, the share of gas consumption in industry increased from 3.8% to 7.6% in total gas consumption. By the end of 2017, a further 55 large-scale coal-fired boilers used in district heating and combined heat and power were retrofitted. It is estimated that incremental gas demand could reach 370 Mcm annually.

After the retrofitting of all industry boilers, about 4 million tons of coal was replaced with cleaner sources of energy, accounting for 90% of all dispersed use of coal in Shanghai. As noted in Figure 4, the industrial demand for gas has been levelling off since 2013. The coal-to-gas switching program only created sizeable demand for gas in industry. In addition, the latest environmental policies are focused on trying to reduce NOx and particles emissions. This implies that the potential for gas demand growth in this sector remains limited.

### 3.2 Impact of seasonality

In Shanghai, gas demand is strongly affected by variations in temperature during the year and presents high seasonality patterns. During the coldest months (December to February), residential consumption increases by about two to three times compared to the summer months as seen in Figure 8. For example, the average residential consumption was 205 Mcm in July 2015 but it more than doubled to about 500 Mcm in January 2016.

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17 Shanghai Economic and Information Commission (2017).
18 Shanghai Economic and Information Commission (2017).
19 Wang et al. (2016).
Moreover, it is evident that seasonality of demand for gas has increased year by year. This will place increasing strain on the exiting supply system. In addition, during the winter times when the supply-demand is tight, gas supply to gas-fired power plants and industry are frequently rationed in order to meet residential demand. In summer, gas-fired power plants are often called upon to meet the peaking power demand, which leads to more volatile dispatch. As a consequence, greater flexibility in the gas supply system will be required.

Figure 8: Seasonality of natural gas demand, January 2009-December 2017 (Mcm)

Source: Data from SNGC, various years.

4 Natural gas supply: meeting the challenge

4.1 Well-diversified supply system

Diversification of natural gas supply sources has always been an important energy development strategy of the municipal government, as Shanghai with very limited indigenous energy production relies heavily on gas imports. After years of development, a multiple supply system has been established with five supply sources, namely the West-East pipeline, the offshore Pinghu pipeline, the Sichuan-East pipeline, Yangshan LNG, and a small-scale Wuhaogou LNG. In 2017, West-East pipeline gas and Yangshan LNG provide about 45% each of the total gas supply, with the other three accounting for the remaining 10% (Figure 9).

Thanks to these well diversified supply infrastructures, Shanghai has managed to meet the growing demand for gas and avoid any gas shortages during peak periods. To further enhance the gas supply capability and diversification, more supply sources are proposed, e.g. the east Russian gas pipeline imports (early 2020s) and the second LNG terminal (mid-2020s). However, there are uncertainties on volumes and timing of these additional supplies. Should there been an unexpected delay in the completion to the east Russian pipeline gas, Shanghai will

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20 Gao (2016).
21 West-East Pipeline include 1st West-East Pipeline (in 2004) and 2nd West-East Pipeline (in 2012).
22 Shenergy (Group) Company (2016).
need to rely more on LNG imports in the mid-2020s. Nevertheless, the level of LNG imports will hinge upon how this supply challenge is tackled.

Figure 9: Share of natural gas supply sources, 2009-2017

![Figure 9: Share of natural gas supply sources, 2009-2017](image)

Source: Data from SNGC, various years.

4.2 The role of LNG

LNG plays a vital role in the diversification of gas supply, especially in guaranteeing the security of supply as noted in the previous section. In addition, LNG has been primarily used to deal with peaks in gas demand by providing much needed flexibility. As shown in Figure 10, out of different supply sources, pipeline gas supplies were mostly flat deliveries, while the LNG supply fluctuates with natural gas demand.

Due to the increasing peaking demand anticipated as a result of high penetration in the residential and commercial market, one viable option is to increase the import of LNG. Given the slowdown of gas demand in recent years, one should proceed with caution when estimating how much additional LNG is required. Based on the business-as-usual scenario - assuming that market demand evolves to 10 Bcm per year in 2020 and that current pipeline supply volumes remain constant, there will additionally be an incremental demand of 1 to 2 million tons of LNG imports per year.

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23 To be clear, this author is not suggesting that there is an actual delay in this on-going Russia pipeline project. He does not have any exclusive information on this matter. He is just hypothetically raising such a scenario to consider how import pipeline supplies into China may be affected in the event of unforeseen circumstances, and the subsequent role LNG will assume as a result.
Figure 10: Daily gas supply curves with different supply sources in 2017 (Mcm)

Source: Data from SNGC, various years.

5 Conclusions

As Shanghai continues its effort in promoting the utilization of clean energy, natural gas is expected to become an important alternative fuel to replace coal. However, in the context of economic transformation and acceleration of industrial structural adjustments, gas demand growth is likely to remain modest in the years to come. It will be mainly driven by economic growth, expansion of grid to areas not previously covered, addition of new gas-fired capacity, and substitution of gas for coal in industry.

At the sectoral level, however, gas demand potentials present differing prospects. Gas use in industry remains limited, while gas demand in the residential and commercial sector will continue to grow. In addition, given the increasing role gas-fired power plant in balancing the system, the expansion of gas use in the power sector is expected. Nevertheless, the level of future gas demand in the power sector will depend on the utilization of gas-fired power units.

The demand for gas in these two sectors implies that in addition to total volumes flexible supply will be increasingly needed in order to match the seasonal residential demand and often volatile dispatch of gas-fired power plants. Because of the specific advantages over pipeline methods, LNG will continue to make an important contribution to the volume and diversity of gas supplies and remain necessary to provide much needed flexibility to meet peak demand.
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